LSPS35XS Piezo Motorized Stage

User Manual

Version : 1.1.0

CAUTION: READ BEFORE OPENING

For safety purposes these instructions must be read before use of this product.

Piezoelectric products are not warranted against mechanical damage resulting from improper use, wherein excessive forces or voltages that are outside specified ranges are applied.

High voltage is present in this product.

Only qualified personnel should work on or around this equipment and only after becoming thoroughly familiar with all warnings, safety notices, and procedures contained herein.

The successful and safe operation of this equipment is dependent on proper handling, installation and operation.

A "qualified person" is one who is familiar with the installation, construction and operation of the equipment and the hazards involved. In addition, he/she has the following qualifications:

- **is trained and authorized to energize, de-energize, clean, and ground equipment in accordance with established practices,**
- **is trained in the proper care and use of protective equipment in accordance with established safety practices.**

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1. GENERAL

Piezoelectric Actuators from CEDRAT TECHNOLOGIES SA consists in a wide range of actuators, divided in four categories:

- Multilayer actuators, that are not mechanically prestressed,
- Parallel prestressed actuators, that are mechanically prestressed multilayer actuators and offer mechanical interfaces,
- Amplified piezo actuators, which use an elastic amplifier to both prestress the multilayer actuator and amplify the displacement.
- Piezoelectric Motor, using Cedrat Technologies actuators to perform millimetric stroke.

Piezoelectric Actuators must be handled carefully. Lifetime of Piezoelectric Multilayer actuators is not limited by wear. They can perform millions of cycles without loss of performance provided they are operated under suitable conditions.

The lifetime of a Piezoelectric Multilayer Actuators is a function of many combined parameters; the most influencing being the applied voltage, the temperature and the humidity. For maximum lifetime, operating voltage should be minimized, especially when they are used in static conditions.

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2. STEPPING PIEZO ACTUATOR PRINCIPLE

Stepping Piezoelectric Actuators are classified as Inertial Stepping Motors (ISM). These motors have the particularity to be based on a single actuator, making the electronic command and control easier.

Stepping Piezoelectric Actuators (SPA) are formed of only four parts (Figure 1): the well-established Amplified Piezoelectric Actuator (APA®), a front mass, a clamp and a rod.

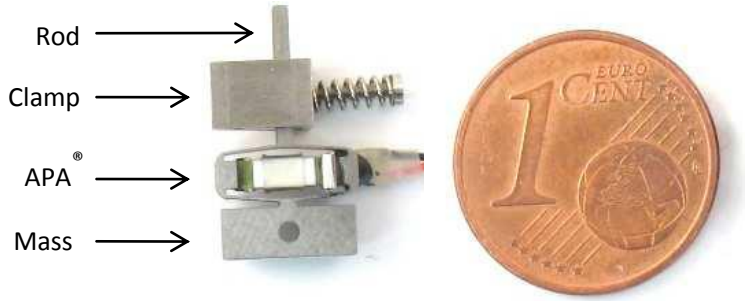

Figure 1 SPA30uXS components

SPA operates by accumulation of small steps, using inertial mode, impact forces and stick-slip effects: Typically, a slow APA® actuation generates a slow motion of the mass while the rod sits in the clamp. A fast APA® actuation induces a fast motion of the rod slipping in the clamp. This allows getting steps, which gives a long stroke, called the stepping mode (M_1). Between each step the actuator stays naturally locked in position. Figure 2 shows the stepping mode principle for fixed clamp and fixed mass configurations. The load can be fixed on different positions leading to two different motor capabilities thanks to different modes. In a first configuration offering nano positioning, the load can replace the mass or can be fixed to the mass. So when the long stroke (M_1) is performed, the motor can be also operated in a deformation mode (M_2) for a fine adjustment. In this case, the stroke is proportional to the applied voltage, which leads to a nanometre resolution and a high bandwidth (limited by motor blocked force). In a second configuration, the load is fixed on the moving rod. In this case, the advantage is a high stiffness, but fine mode is no more available.

The proposed kit uses as standard configuration the fixed mass configuration. However, developers have the possibility to experiment the other configuration using the “Extracted configuration”

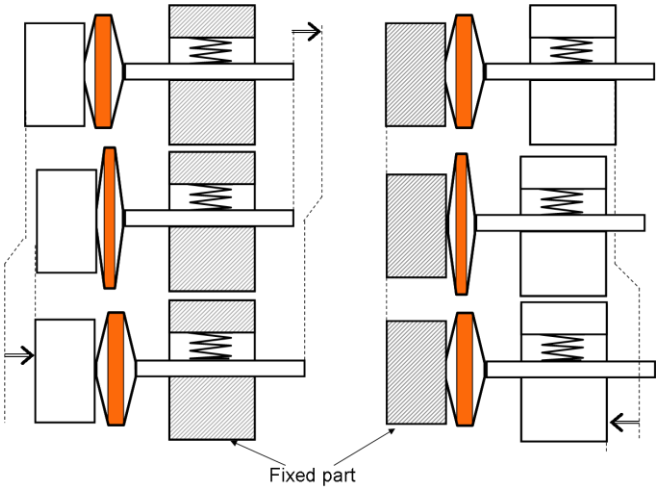

Figure 2 Working principles for 2 different configurations

The long stroke stepping mode (M_1) is produced by step accumulation with an appropriate 0-150V voltage pattern. The short stroke deformation mode (M_2) is produced by deformation of the APA®, which is simply proportional to the voltage excitation between –20 to +150V. Only one amplifier channel per SPA is required.

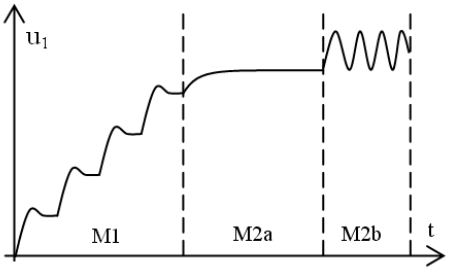

Figure 3 SPA stepping mode (M_1) and deformation mode (M_2)

Compared to a piezo stack of the same size, an APA presents a typically 20 to 100 times larger compliance and a four to ten times larger stroke. The larger compliance of the APA leads to a 5 to 10 lower resonance frequency (at constant

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mass) and so a 5 to 10 times smaller current demand than the same piezo capacitance in a stack.

The large deformation stroke of the APA is also an advantage. It provides a useful deformation stroke mode (M_2). It also contributes in getting good speed in long stroke mode (M_1): larger steps per cycle compensate a lower step frequency.

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3. THE LSPS35XS AND ITS CONTROLLING BOARD SPC45

The LSPS35XS is a one axis linear stage. It includes a motor LSPA35XS, a linear guiding and a 1.95µm resolution position sensor. The controller is the SPC45 board. The SPC45 controls in closed loop the LSPS35XS and is configurable with a Graphical User Interface (GUI) through a USB plug. The input command can be done with the GUI or with an analogical signal (0..5V)

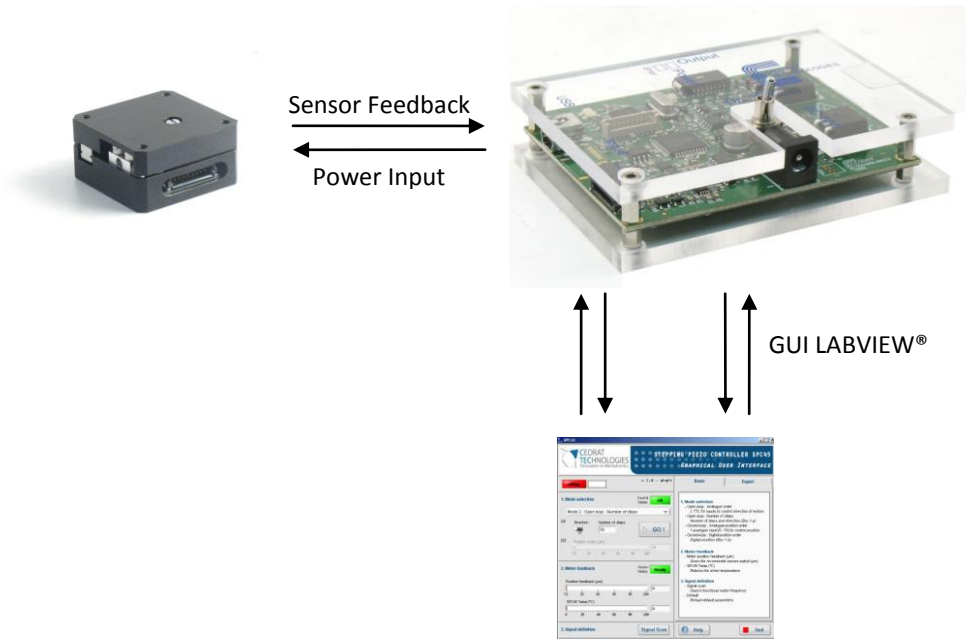

Figure 4 Synoptic of the control of the LSPS35XS

3.1. LSPS35XS DESCRIPTION

3.1.1. Overall

The LSPS35XS works on the principle of the LSPA motor. The amplified piezo actuator used is the APA35XS. The APA35XS is a standard and proven actuator from Cedrat Technologies.

Figure 5 APA35XS

A stage LSPS35XS has one axis of motion. A linear rail limits the parasitic displacements in other directions and protects the system from external torques and forces. A linear position sensor is also integrated. It has a resolution of 1.95µm and a range of 10mm.

3.1.2. Mechanical interfaces

The mechanical interfaces of the LSPS35XS are given below.

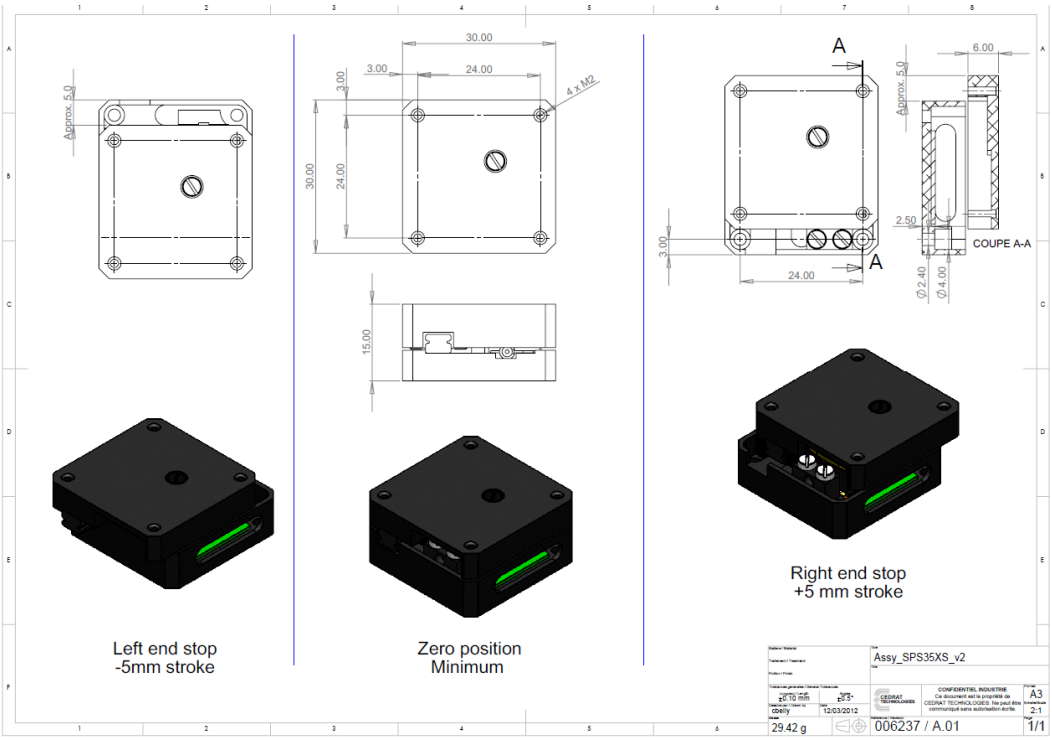

Figure 6 Mechanical interfaces of the LSPS35XS

3.1.3. Electrical interfaces

The LSPS35XS is provided with an 8 pins connector. The function of each pin is given in figure 8

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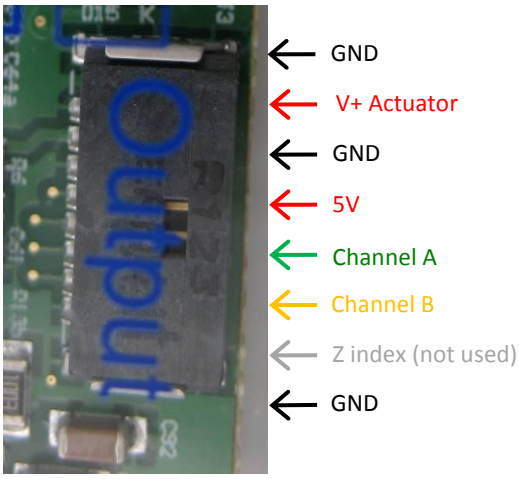

Figure 7 Electrical interfaces of the LSPS35XS

3.1.4. Incremental magnetic sensor

The integrated incremental magnetic sensor gives the possibility to reach a 1.95µm resolution in motion. The sensor is powered with a 5V voltage. Two output TTL channels (Channel A and B) are available in order to be decoded to produce a count up pulse or a count down pulse. The decoding operation is done by the proposed driver SPC45 (see §7.4).

3.2. SPC45 DESCRIPTION

The Stepping Piezo Controller SPC45 is the driver board of the SPS35XS. It includes control functions, digital and analogue interfaces, and serial communication ports. The SPC45 is powered with the provided standard AC/DC adapter (24Vdc). Description of the SPC45 interfaces is given in Figure 9.

WARNING! Be careful when plugging a cable to the SPC45 board. Connection of the input cable to the output connector (or reciprocally) could lead to severe

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damaging of the electronics. **Always verify your connections before switching on the electronics.**

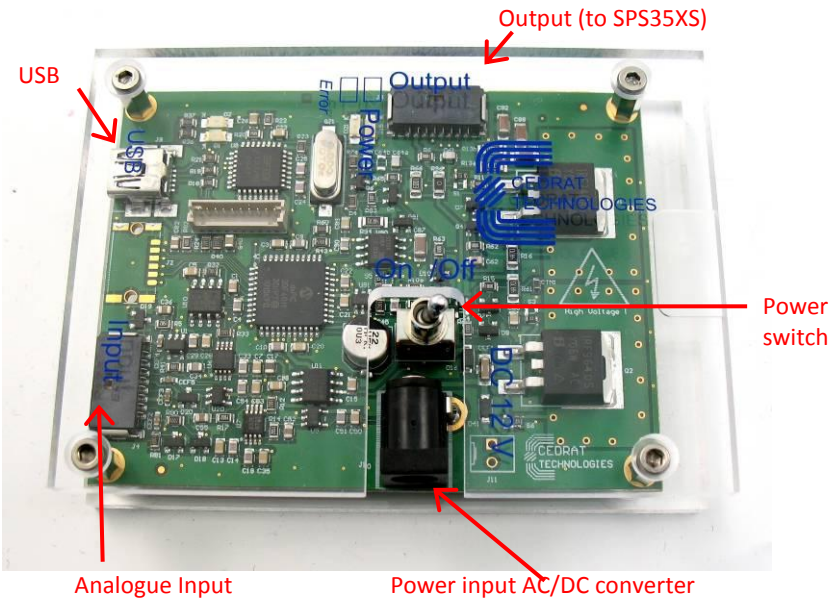

Figure 8 SPC45 description

Input and output of the board are physically given in Figure 9 and Figure 10 and detailed on Table 1.

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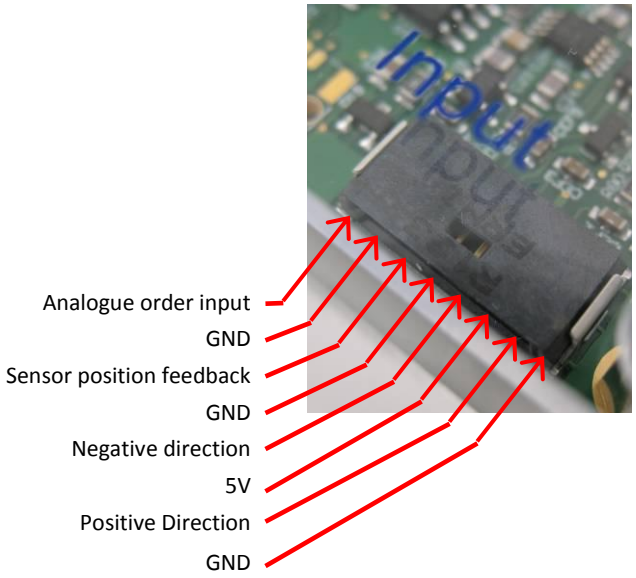

Figure 9 Input connector details

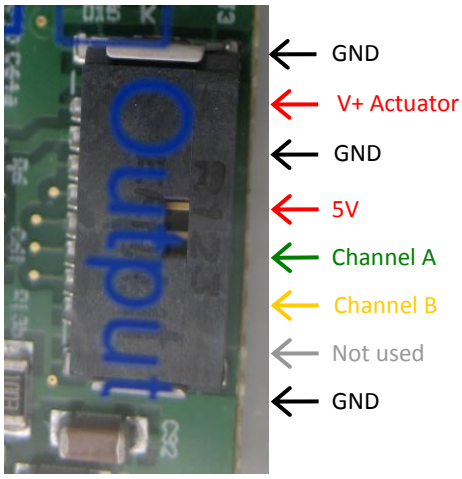

Figure 10 Output connector details

Number	Description	Range	Nature
IN08	Analogue order input	[0 : 5] V	In
IN07	GND	-	-
IN06	Sensor position feedback	[0 : 5] V	Out
IN05	GND	-	-
IN04	Negative	TTL (0 or 5V)	In
IN03	5V	-	Out
IN02	Positive	TTL (0 or 5V)	In
IN01	GND	-	-
OUT01	GND Actuator	-	-
OUT02	V+ Actuator	[0 : 110] V	Out
OUT03	GND Actuator	-	-
OUT04	5V	-	Out
OUT05	Channel A	TTL (0 or 5V)	In
OUT06	Channel B	TTL (0 or 5V)	In
OUT07	Z index	TTL (0 or 5V)	Not used
OUT08	GND sensor	-	-

Table 1 SPC45 port description

Please notice that connector reference are the following one: ERNI 8b RA 1,27

Cables used are cables 1,27 mm ERNI Minibridge, 8 points.

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3.3. LSPS35XS PERFORMANCES

The performances presented in the following table are results of tests performed with no load, in lab conditions. Additional payload may have consequences on performances.

			Unit		LSPS35XS
Notes					
Base					APA35XS
Mastered motions					TX
Max. No-load displacement			mm		10
Holding force without cunsomption			N		3
Max speed	*Unloaded, with adapted driver*		mm/s		30
Max step size	*Unloaded, with adapted driver*		µm		38
Max driving force			N		1
Typical max loading			gr		70
Typical working frequency			Hz		800
Typical stepping mode resolution	*With adapted driving parameters*		µm		1
Deformation stroke			µm		55
Linear, Angular resolution			nm		0.55
Stiffness			N/µm		0.49
Capacitance			µF		0.25
Voltage range			V		-20 … 150
Out of plane			µm		6
Z rotation			mrad		0.3
X Y rotation			mrad		0.3
Typical Lifetime	*Unloaded, , full speed, 50% duty-cycle*		cycles		1.00E+06
Sensors option					MAG
Heigth			mm		15
Width			mm		30
Length			mm		30
Mass			g		30
Unloaded resonance frequency (in the actuation's direction)			Hz		909
Mechanical interfaces (payload)					4 x M2 deep. 6
Mechanical interfaces (frame)					2 x diam 2.4 holes
Electrical interfaces					8 pins ERNI connector

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4. ENVIRONMENT COMPATIBILITIES

Stepping Piezo Actuator has a few heritages from various environment compatibilities. Vacuum compatibility can be achieved via some precautions, with or without sensor.

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5. GRAPHICAL USER INTERFACE

The Graphical User Interface (GUI) is built to give the user the opportunity to control the system, in open or closed-loop, but also to give feedback about system state.

5.1. SOFTWARE INSTALLATION

This paragraph describes the different instructions to connect the SPC45 driver and to install the software.

Do not connect the USB driver on the PC before installing the software.

The installation is simple: Updated software SPC45 may be downloaded from Cedrat Technologies website. Please check:

http://www.cedrat-technologies.com/en/mechatronic-products/soft-download.html

It includes the installation of the drivers to dialogue with the SPC45 and the installer for the application software. It contains the autonomous application too.

5.1.1. Required equipments

You must install the Software on the following Personal Computer configuration:

- Change "," in "." in the regional configuration of your PC if it is not the case. (Settings/ Controls Panel / Regional and language Options / Customize / Decimal symbol).
- Software is optimized for 1600x900 screen resolution.

5.1.2. First time installation

- The operator has to run the "setup.exe", following the given instructions.

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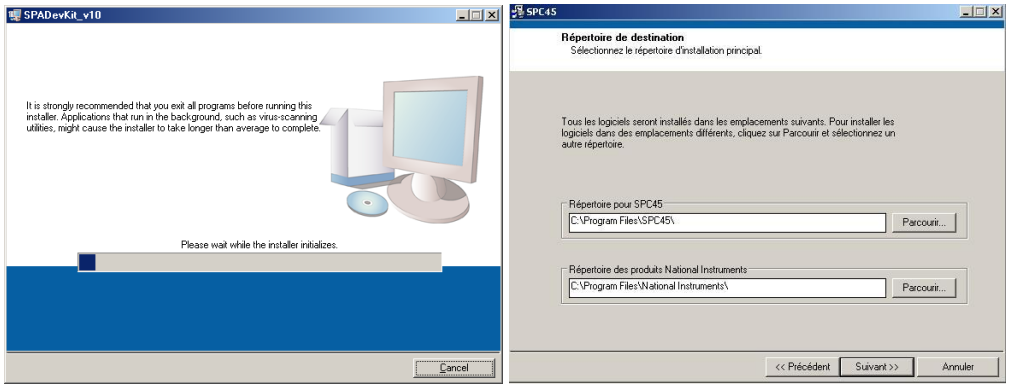

Figure 11 Destination directory

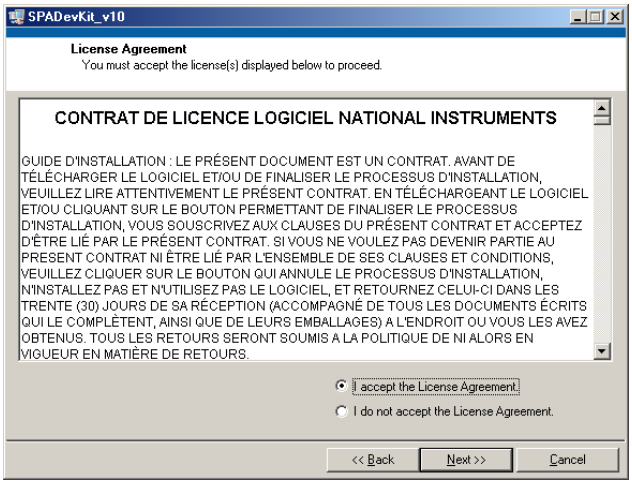

Figure 12 License Agreement

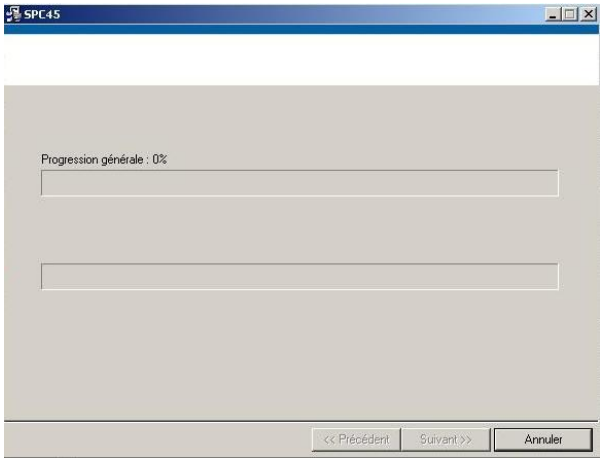

Figure 13 Starting Installation

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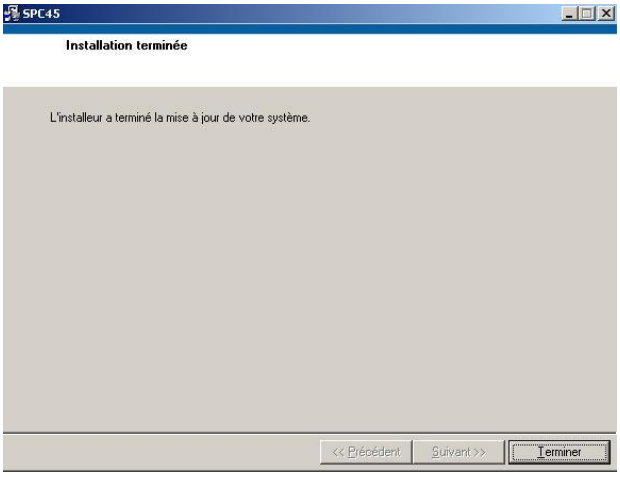

Figure 14 Installation finish

- After this installation is finished, another driver is installed automatically. The system shall be **restarted**.

- Connect your PC with the SPC45 by USB cable and power on the driver.
- Now the operator can run the software "SPC45.exe"

5.2. OVERALL DESCRIPTION

The control software interface is made of a few boxes.

The first one concerns the choice of the working mode of the system. Some modes need additional parameters definition, which are detailed further.

The second box corresponds to the parameters feedback from the system, and especially position.

The communication channel is automatically detected when the software starts.

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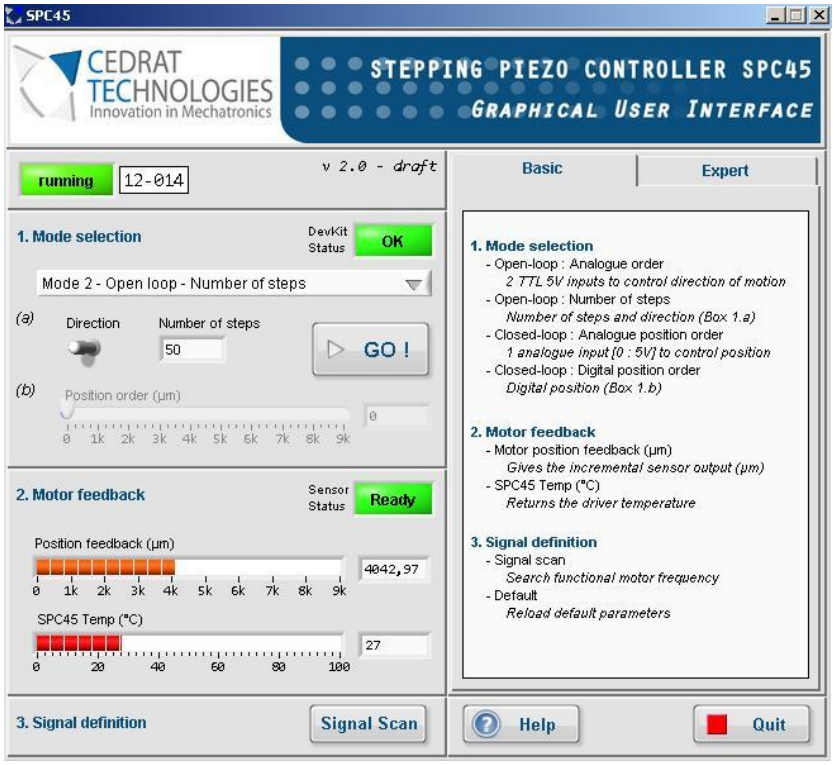

Figure 15 Graphical User Interface SPC45

5.2.1. Communication

Before running the GUI, please plug the SPC45 driver, power it and connect the driver to the computer using provided USB cable.

The port COM is automatically detected by the software. If the communication is well established, the Running indicator turns green.

If the driver is not available, not plugged, or not powered, the communication fails and status indicates “offline”. An additional warning message appears (Figure 16).

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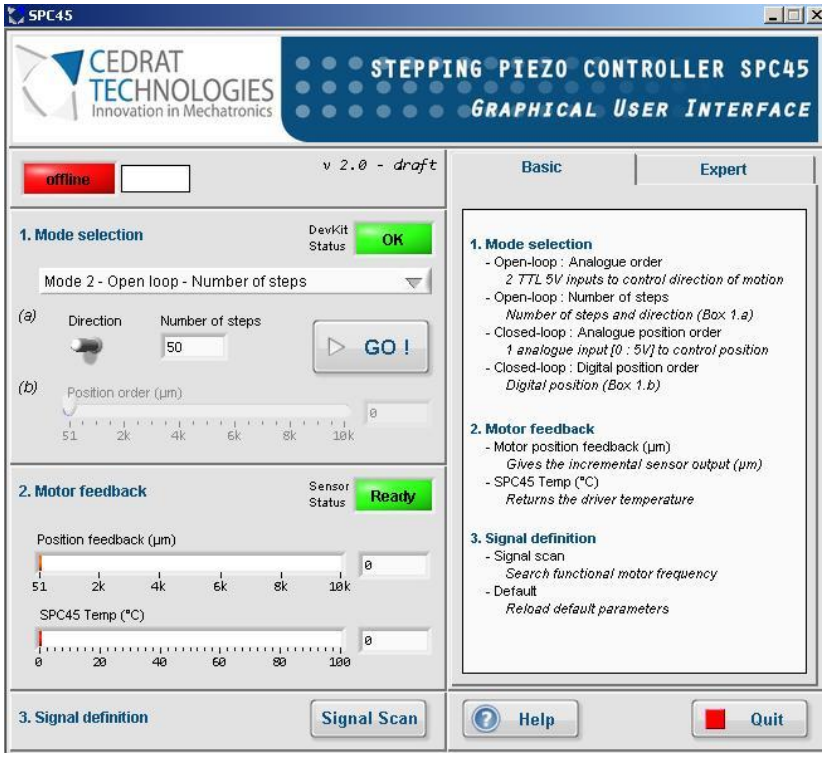

Figure 16 Waiting message

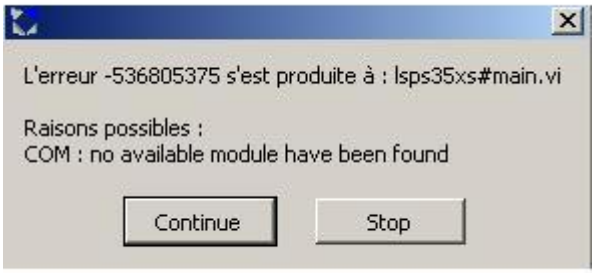

Figure 17 Communication error

If this problem occurs, you have to restart the software ensuring to connect the USB cable correctly and to power ON the SPC45 before launching the SPC45.exe.

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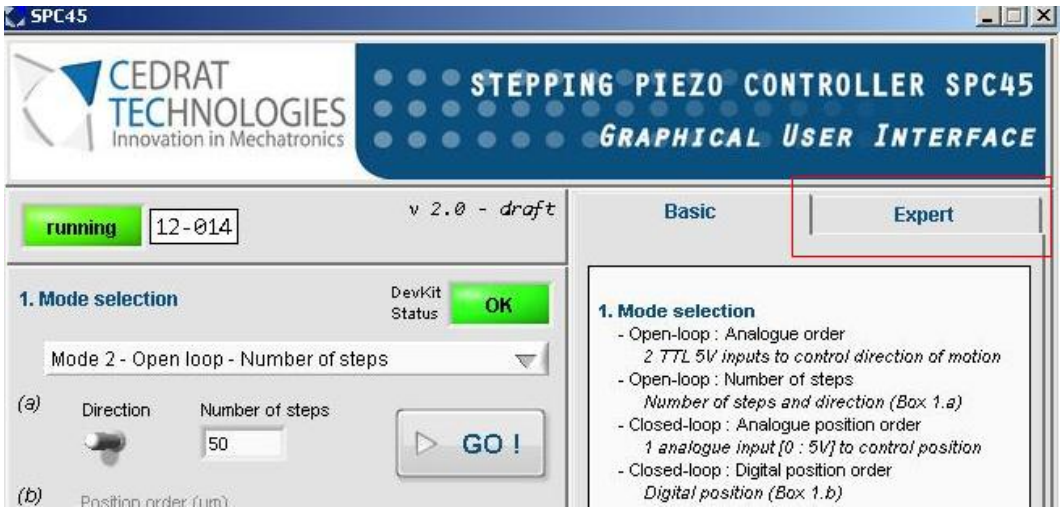
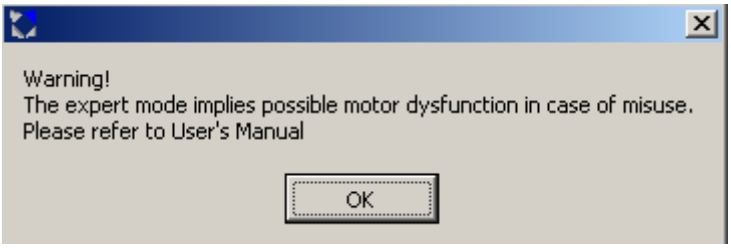
5.2.2. Load configuration

The Graphical User Interface SPC45.exe can be used for several products from Cedrat Technologies. Consequently, it is needed to load the default configuration for of your system item. For that, go into the "Expert" mode:



Click "OK" on the warning message



Click on "Load":

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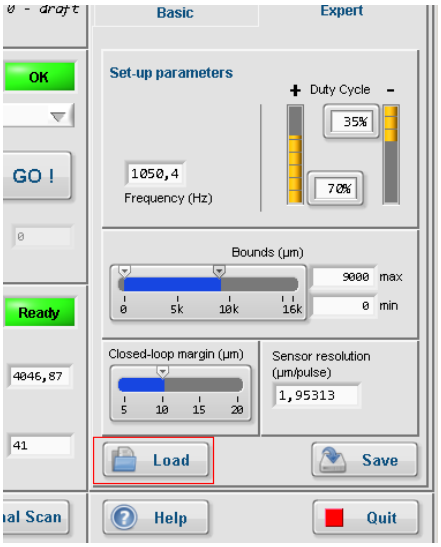
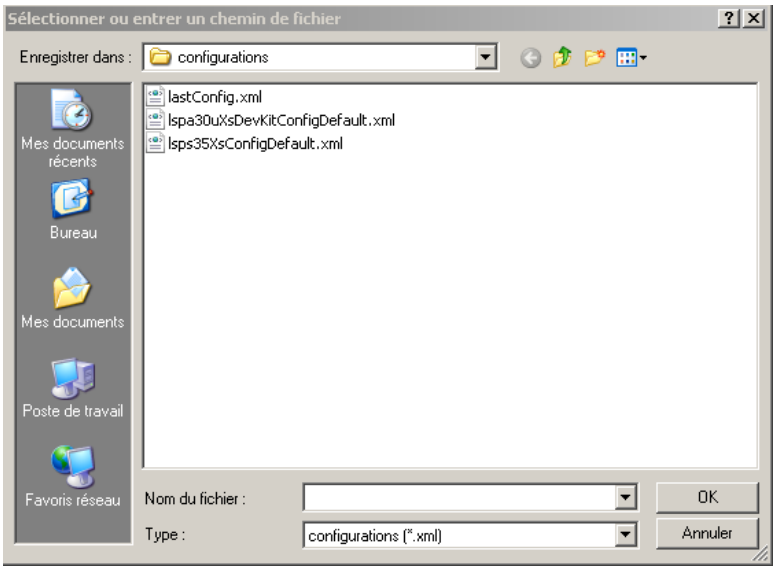


Select and Open the file “xxxxConfigDefault” corresponding to your product:



The GUI is now configured for your product. Leave the expert mode by clicking back on “Basic”:

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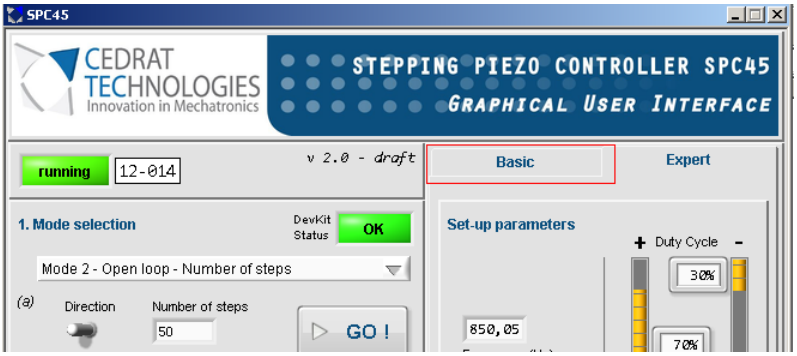

The GUI is ready to be used with your product.

5.2.3. Mode choice

The user interface allows the user to choose the working mode. Each of them is detailed further.

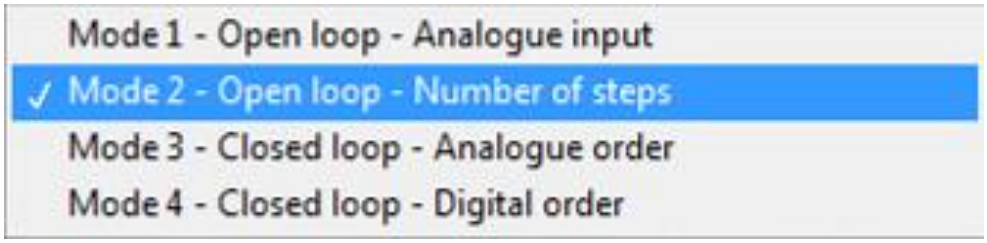

Figure 18 Mode choice

5.2.3.1.Mode 1: Open-loop: Analogue input

Especially designed for demo purpose, this mode allows using two TTL (0-5V) inputs, in order to control the direction of the system motion. Please refer to Figure 16 to see input positions (Positive and Negative direction).

5.2.3.2.Mode 2: Open-loop: Number of steps order

This mode gives the possibility to send to the system an order as a specific number of steps in the chosen direction. The software updates and monitors automatically the position feedback.

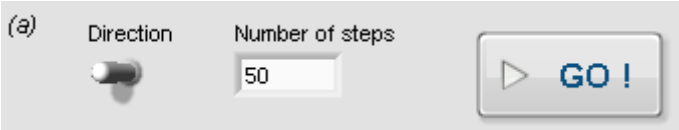

Figure 19 Direction and number of step definition

Enter Number of desired Steps, select direction and Run the motion. After the motion, the position feedback is automatically updated (see §5.2.4).

5.2.3.3. Mode 3: Closed-loop: Analogue position

The "Closed-loop Analogue position" mode is available when a sensor is detected by the driver SPC45. This detection is done when the driver is turned on. If sensor is not detected, the Red LED on SPC45 driver lights.

The input range is [0 ; 5] V. The system automatically reaches the desired position.

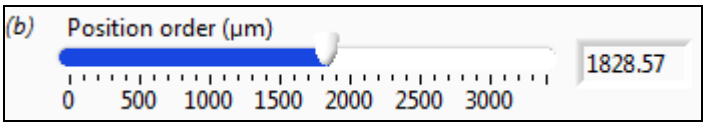

Figure 20 Digital closed-loop order

5.2.3.4.Mode 4: Closed-loop: Digital position

The "Closed-loop Digital order" mode is only available when a sensor is detected by the driver SPC45. This detection is done when the driver is turned on. If sensor is not detected, the Red LED on SPC45 driver lights.

The desired position (µm) is selected using the input bar cursor or the Digital control. Then run the system motion using RUN button. The Position feedback (µm) is automatically updated after the motion.

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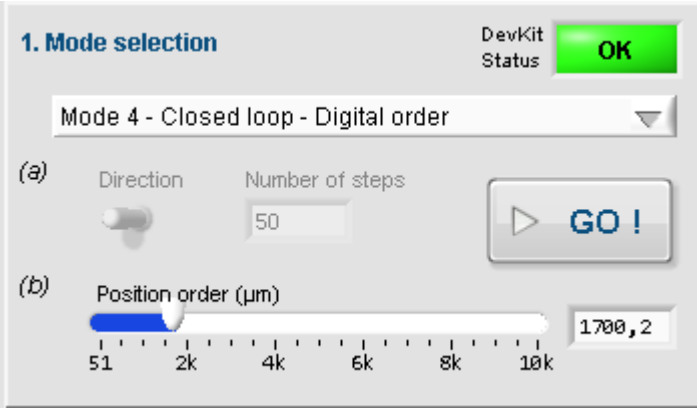
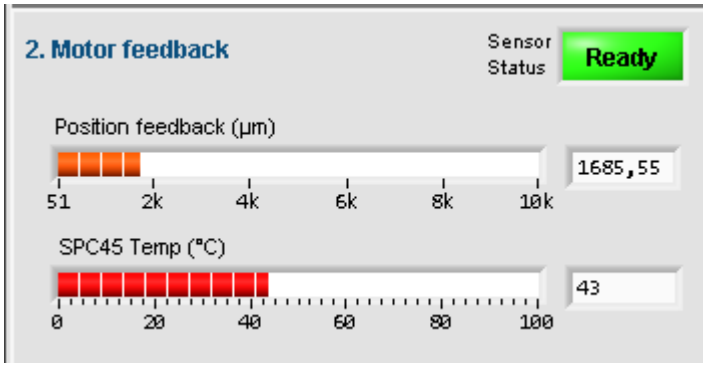


Figure 21 Closed-loop interface

If Mode 4 is the only mode unavailable, please refer to § 5.1.1 to change regional configuration.

5.2.4. System Feedback

The user interface gives a feedback. This includes the position and driver temperature. During "Open-loop: Analogue input" mode and "Closed-loop: Analogue order" mode, system status update is done 5 times per second. This would also update values from Maintenance sheet (see §8).



5.2.5. Signal definition

The signal definition box (#3) is composed of two buttons. The first one, called "Signal scan", allows the driver to look for a convenient input signal. This is done automatically, and takes a few seconds. If closed-loop mode is used, the system takes place to the previous position order as soon as the "Signal scan" is finished.

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Note that this function may not give useful feedback, especially if loading is not correct and/or mechanical stops are strongly involved. Load the default configuration if the system seems to be inefficient after the Signal Scan. (§5.2.2)

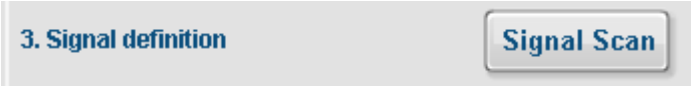

Figure 22 Signal definition box

5.2.6. Missing sensor

If you are not using the provided sensor, or if there is connection problem, the SPC45 driver is not able to return position feedback from sensor. The GUI indicates a “sensor missing” message, next to the Position feedback indicator.

Figure 23 Sensor status

5.3. OPERATING THE SYSTEM WITHOUT GUI

Mode 1 and 3 (Analogue modes) are fully usable without GUI. For other modes: the SPC45 driver is commanded using serial digital inputs. Listing of the serial commands needed to communicate with the SPC45 driver may be furnished. Please contact us to get further information.

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6. OPERATION OF THE SPC45

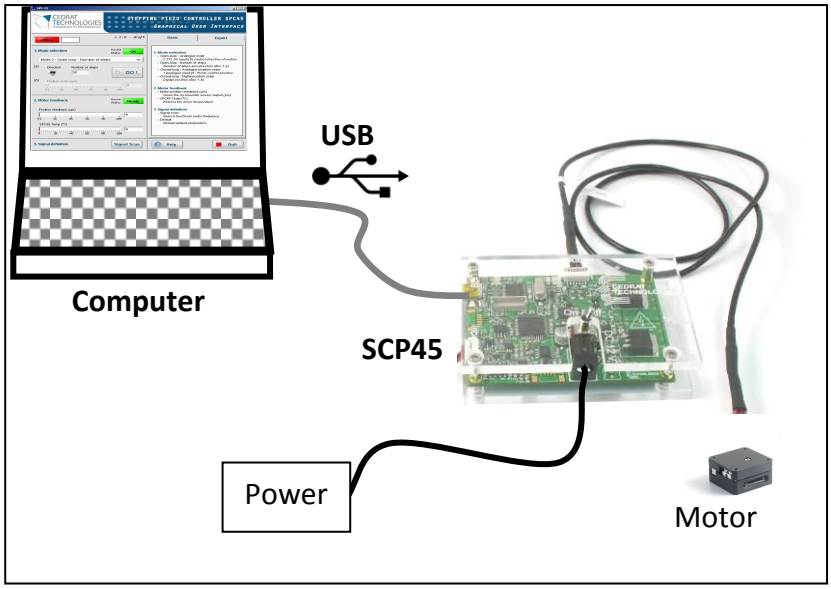

Figure 24 Standard configuration

6.1.1. Procedure:

(01) Check the content of the delivery If any component is missing, please contact Cedrat Technologies.

(02) Plug the SPC45 driver to the motor platform using the provided standard cable.

(03) Plug the SPC45 driver to a computer using the provided USB cable.

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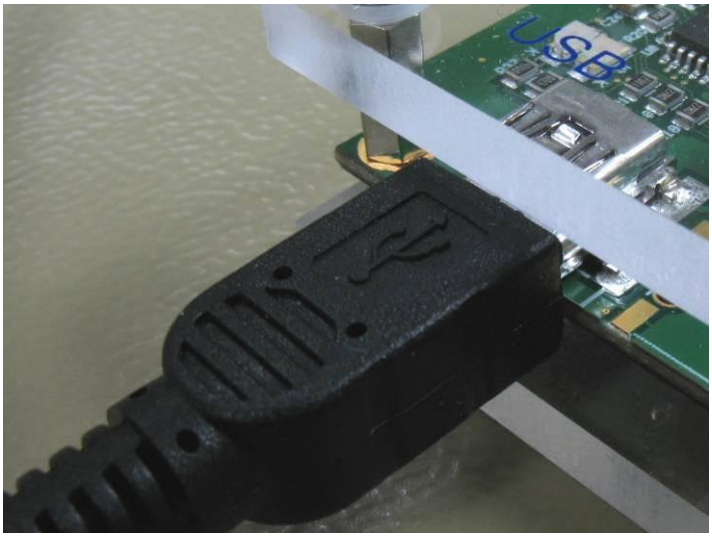
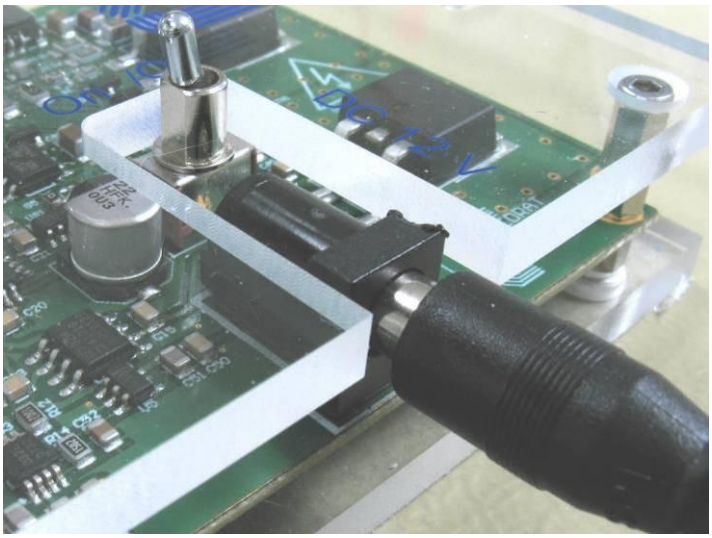


(04) Plug the power adapter to the driver SPC45. Turn on the Power switch.



(05) Launch SPC45.exe. Please refer to § 5.1 to get information about software installation.

(06) Wait for the communication between the computer and the driver is settled.

(07) Choose the desired control mode (Open-loop - Number of steps order OR Closed-loop – Digital order). Note that the two other modes are unusable without analogue input, so they are not convenient in “plug-and-play” configuration.

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(08) Please refer to § 5.2.3.2 and § 5.2.3.4 to obtain information about these modes way-of-working.

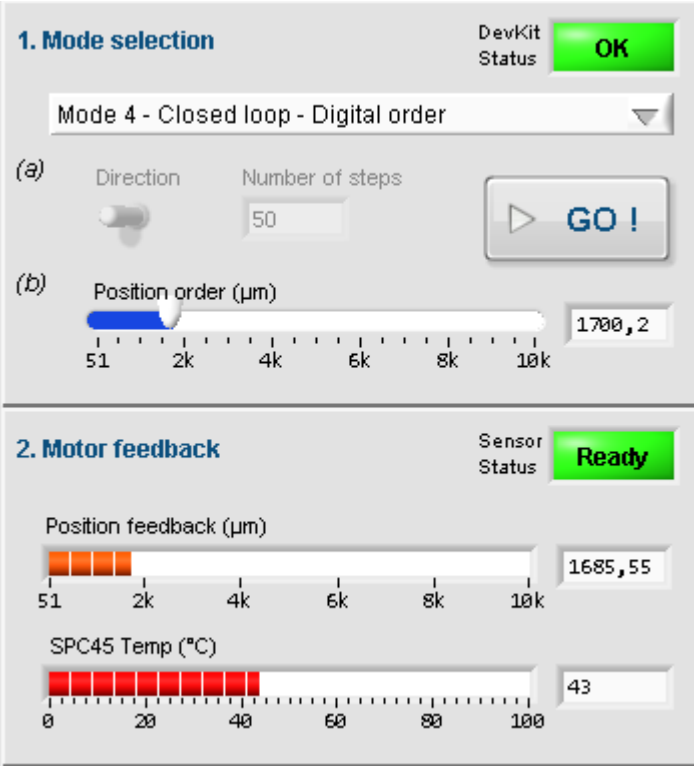


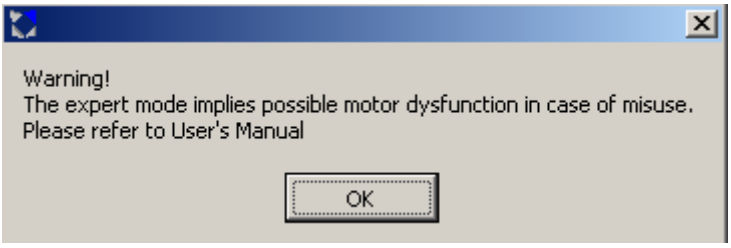
Figure 25 Software interface

7. EXPERT MODE

This part details information about possibilities offered to expert, who wants to dedicate the system configuration to their own application. By the way, expert may adapt the system to fit their own mechanism specification.

Do not try to change any of the following parameters if you are not sure to use the system in the correct way.

All of the possibilities described here are accessible by activating the “Expert Mode” tab on the GUI. When clicking on it, the following message informs you to refer to this part of the User’s Manual.



7.1. SYSTEM COMMAND SIGNAL DEFINITION

The LSPA and LSPS systems are using a specific waveform to generate the motion. This waveform has been settled to allow users to load the system with small loadings. For other loadings, “Signal Scan” function (see §5.2.5) allows driver SPC45 to look for an adapted input signal. However, expert may manually improve the signal definition to improve system performances.

The user interface gives the expert the possibility to change the parameters of the system input signal. The main rule of the frequency change is explained by Figure 27. With load, the optimal frequency decreases. According to user’s payload, the signal frequency may have to be changed.

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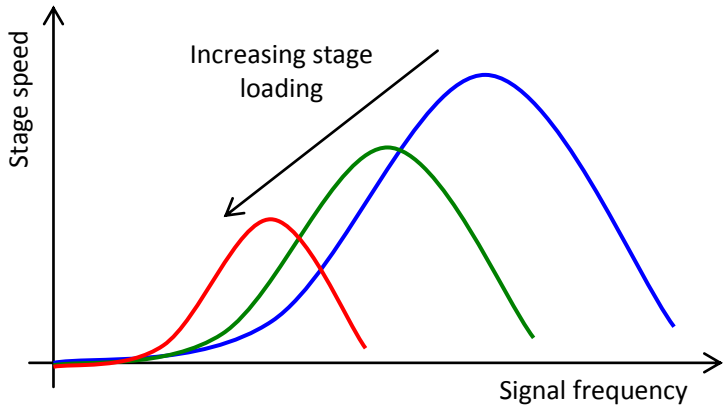

Figure 26 Example of signal frequency influence on speed for several loadings

The Graphical User Interface allows to impact on the signal frequency. It consists in indicating directly the desired signal frequency to the controller.

Two others parameters accessible are Duty cycle for each direction. Figure 28 shows the impact of signal duty-cycle variation on system speed. It can be seen that optimal values are reached for approximately 35% and 70%. These values are set as default values.

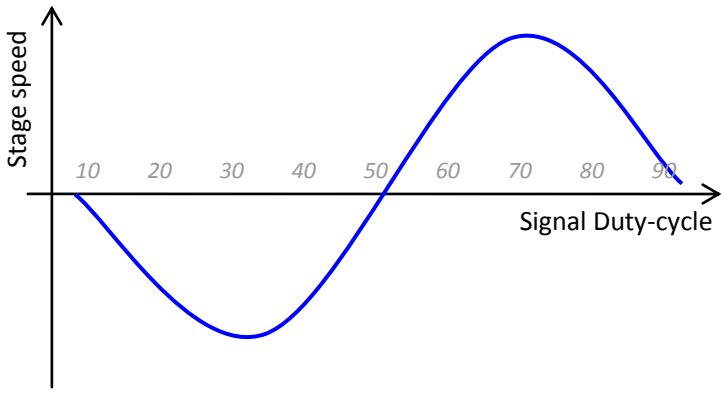

Figure 27 Duty-cycle influence principle on system speed

The user interface is presented in Figure 29

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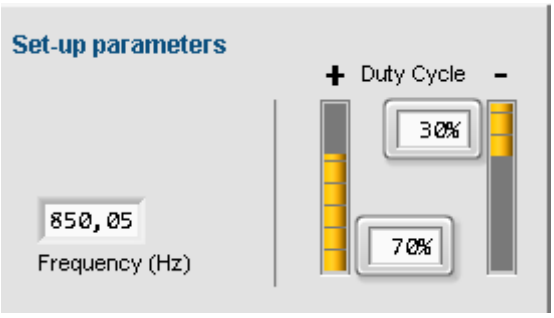
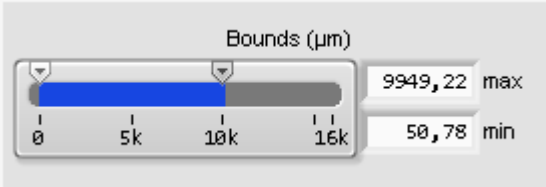


Figure 28 Signal Expert definition

7.2. DEFINE BOUNDS

It is possible to define numeric bounds for the system. This option can be used in order to limit the motion of the system in a given window. The bounds will only be taken into account in "Mode 4 – Cloased loop – Digital Order"



7.3. CLOSED-LOOP MAX ERROR

WARNING! Changing the value of the maximum positioning error might lead to unstable control.

The closed-loop mode is done by an on/off control. While the error, defined as the difference between the position order and the position feedback is bigger than the max error, motion is performed. Figure 30(a) explains this principle.

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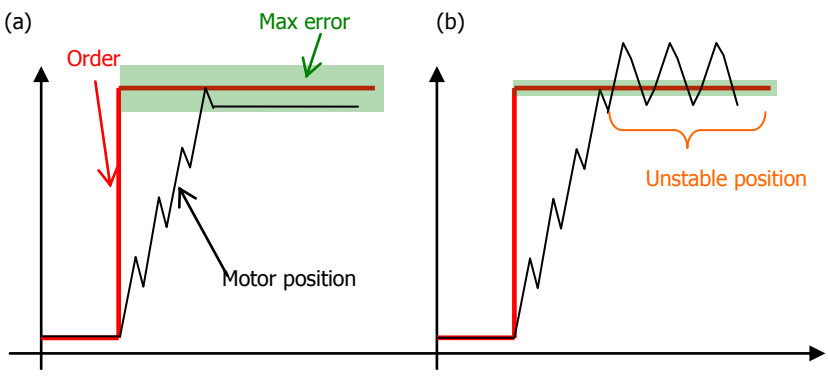

Figure 29 Closed-loop principle and instability risk

The main drawback of this control solution is the instability created by the discrete behaviour of the controller. Indeed, once the maximum error is below standard step size, the system may have major difficulties to reach the desired position. Figure 29 (b) presents an example of this situation.

The maximum error may be changed using the following cursor (see figure 31), available at the front panel of the Expert tab.

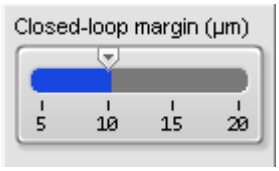

Figure 30 Max error setting

7.4. OTHER INCREMENTAL SENSOR INTEGRATION

WARNING! When the sensor is changed, if the closed-loop control is unstable or direction of motion reversed, this might result from the inversion of the channels. Swap the channels connections and try again.

The driver SPC45 allows interacting with any incremental sensor, using two 5V-TTL-Logic signals. Provided sensor gets a 1.95 µm resolution. This gain, defined as the standard value is visible on the GUI (see fig 32). It has no reason to be changed as long as the provided sensor is used.

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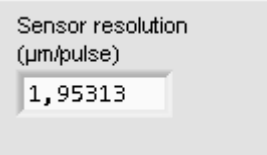

Figure 31 Sensor resolution setting

However, user's test bench may already have its own incremental sensor. In this case, sensor resolution can be changed in order to fit considered sensor resolution.

7.5. "LOAD" OF "SAVE" CONFIGURATION

It is possible to load or save a given configuration thanks to the buttons "Load" and "Save".

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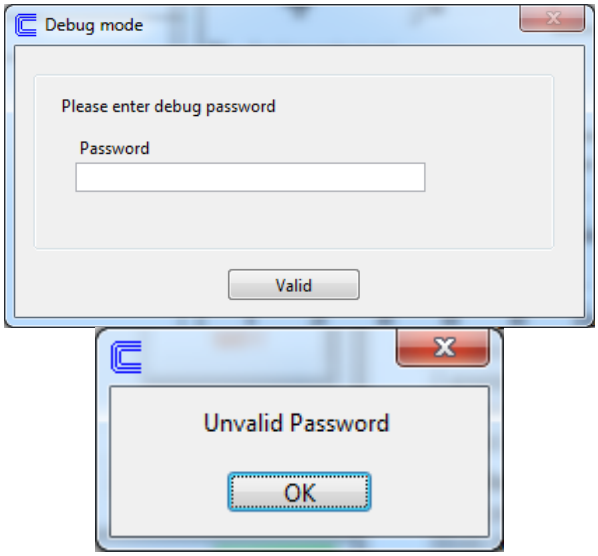
8. TROUBLE SHOOTING FORM

Error diagnostic may be helped using the following graphs. Please identify your problem and refer to associated protocol.

Problem	Protocol
The system doesn't move when motion is requested	0
The system moves but not correctly	1
Communication with the SPC45 driver is not working	2
My problem is not fixed	3

For advanced debugging, Maintenance Tab includes information about SPC45. This Tab is locked by a password. Please contact Cedrat Technologies if you meet problems and want to unlock this Tab.



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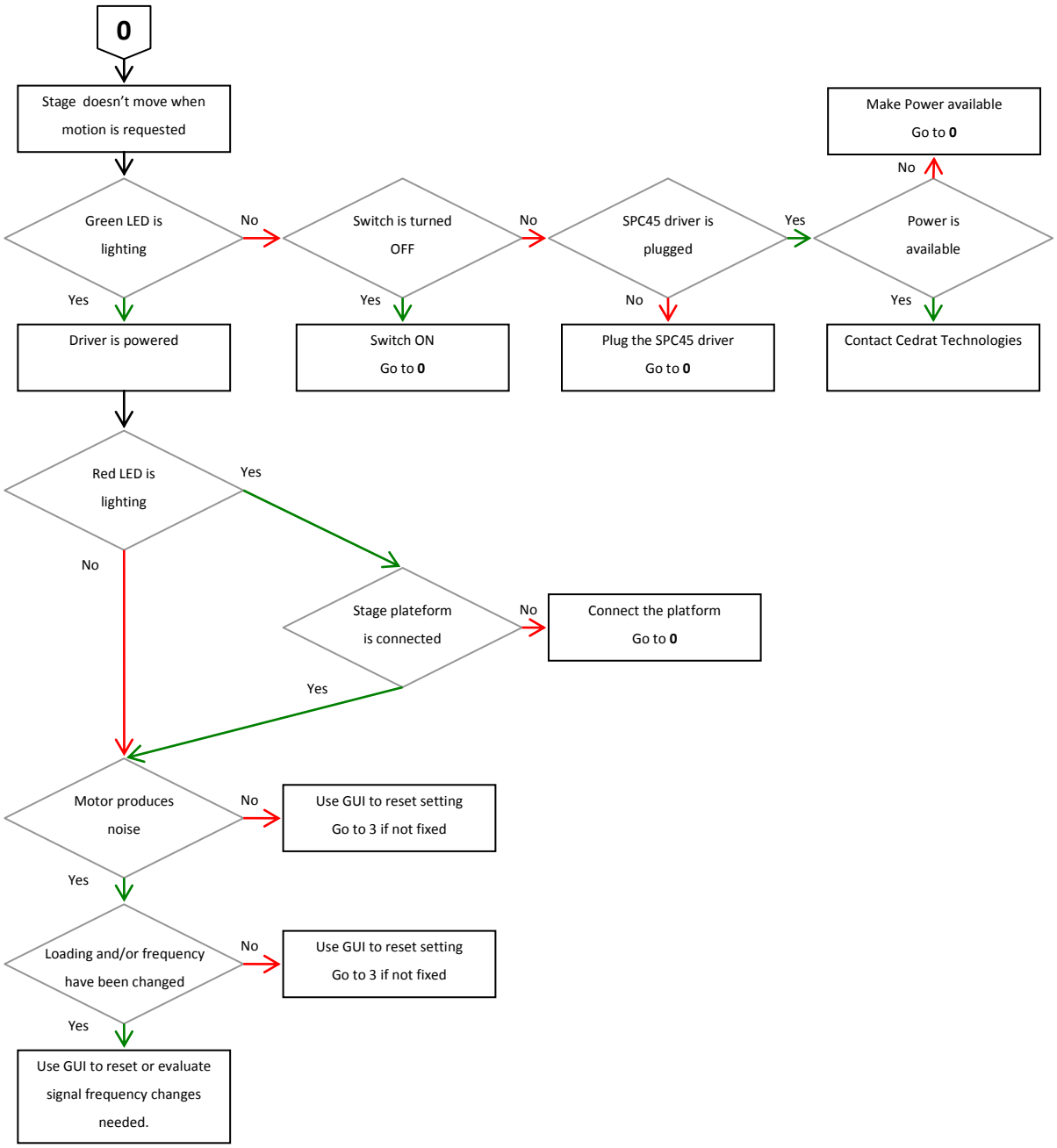

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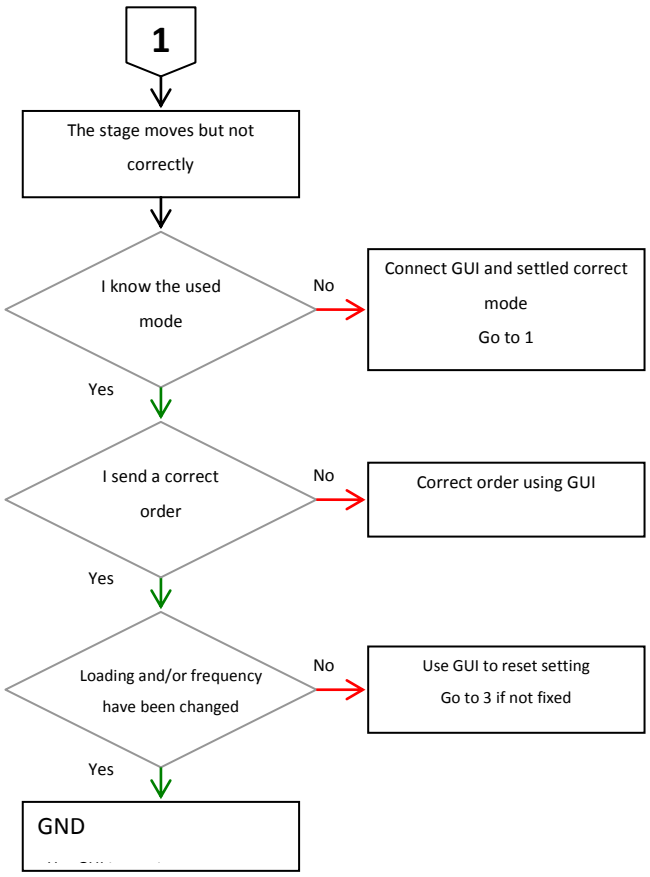

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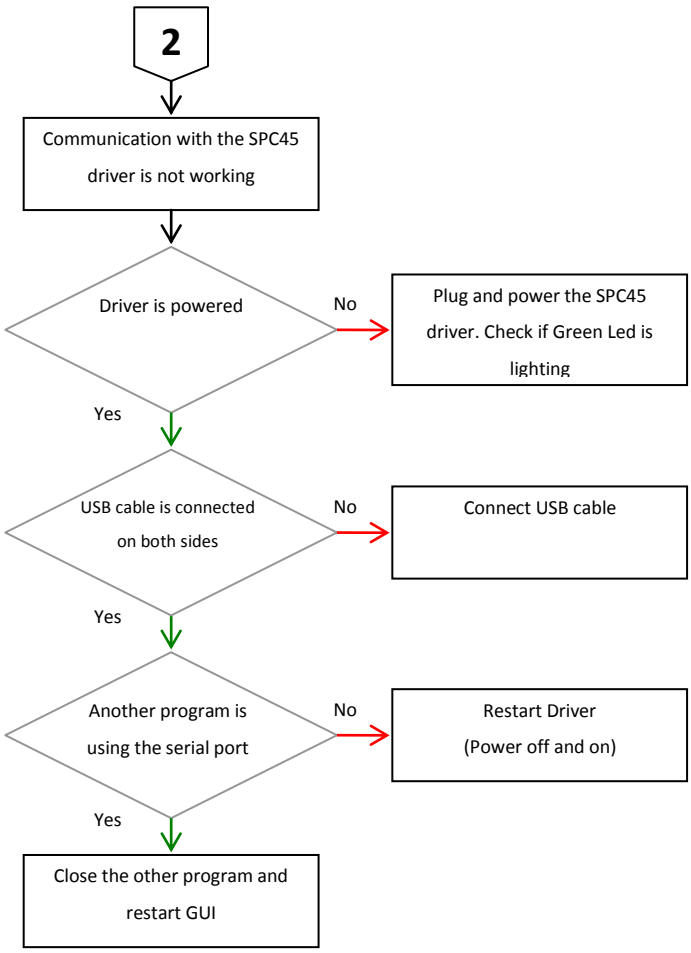

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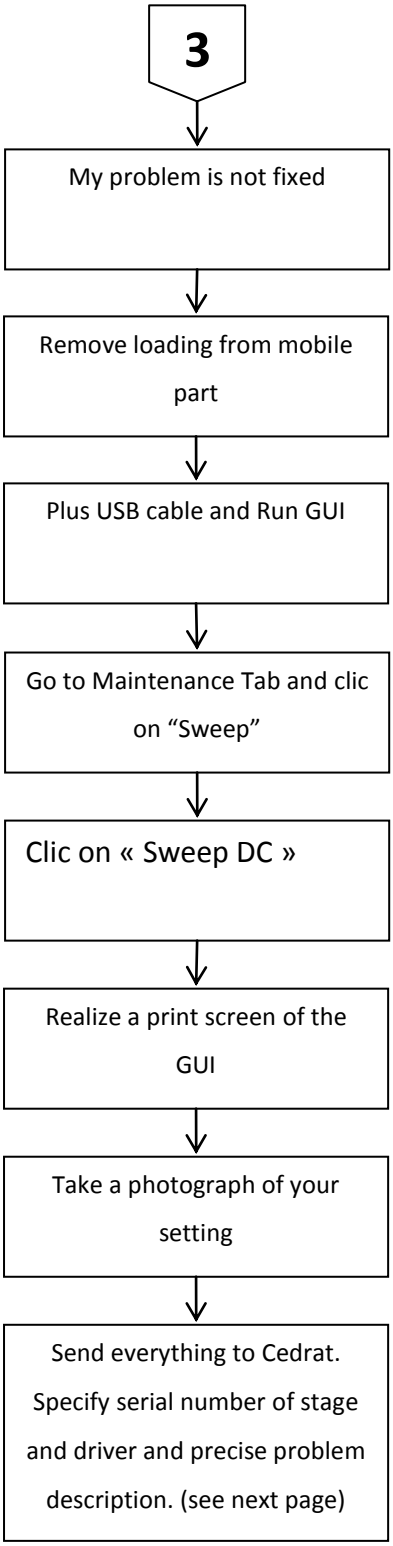

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If you don't find the solution to your problem using the proposed trouble shooting form, please contact your vendor with the following information:

Product: Please give mention here the references and delivery date,
History: Please summarize here every action which has been performed with the device since the delivery,
Problem description: Please describe here the problems

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9. WARRANTY CONDITIONS AND EXCEPTIONS

The equipment is warranted for a period of one year from date of shipment, including parts and labor, and only under standard technical conditions as outlined above and expressly mentioned in the technical data sheet. Repairs will be carried out at Cedrat Technologies or through your vendor. During the warranty period, Cedrat Technologies will, at its option, either repair or replace products which prove to be defective.

Interventions or attempts to service or repair the Actuators by any unauthorized persons will invalidate this warranty.

In addition, this warranty will not apply if the SPS35XS or SPC45 Driver are subjected to any of the following:
improper handling, including, but not limited to, shocks and abrasions
improper installation, including, but not limited to, excessive mechanical forces and moments, failure to use the standard electrical and mechanical interfaces
excessive voltage, including, but not limited to, peak values outside the recommended operating range, DC values applied for excessive time periods
inappropriate environmental conditions, including, but not limited to, high temperatures or high humidity

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10. INSPECTION UPON RECEIPT

This product has been inspected and shown to operate correctly at the time of shipment.

Immediately upon receipt of the product, it should be inspected carefully for any signs of damage that may have occurred during shipment. If any damage is found, a claim should be filed with the carrier.

The package should also be inspected for completeness according to the enclosed packing list. If an order is incorrect or incomplete, contact your distributor.

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11. NOTES

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